3.3.4. Dynamic Maneuvering Position Accuracy

3.3.4.1. Purpose

The purpose of this test is to measure the dynamic maneuvering accuracy of the INS, to isolate the effects of various types of aircraft maneuvers and to qualitatively assess the utility of the INS as a navigation aid in the maneuvering environment.

3.3.4.2. General

Dynamic, non-maneuvering position accuracy testing provided a baseline of accuracy which included the effects of strictly non-maneuvering flight. Using this baseline plot, the aircraft will perform a series of maneuvers with flyover points taken after each maneuver. The exact flight profile will have little effect upon the accuracy compared to the effects of maneuvering. For this reason, a single flyover point can be repeatedly used. A significant departure from the dynamic baseline data plot will be due to aircraft maneuvering. In this way, the effects of mission relatable maneuvering upon INS accuracy will be isolated from other effects. Low acceleration roll, pitch (a loop maneuver will be used) and yaw maneuvers will be used to check for gimbal limits. Airspeed limitations will be checked while linearly accelerating from zero to the airspeed limit of the aircraft. Rolls, pitch, yaw, climbs, descents, and level turn maneuvers to the limits of the aircraft will be used to assess the effects of maneuvers in a single plane. Finally, rolling push-overs and pull-ups will be performed to the aircraft limits to check the effects of multi-axis maneuvers.

3.3.4.3. Instrumentation

A stop watch and data cards are required for this test, a voice recorder is optional.

3.3.4.4. Data Required

Following an initialization and alignment test, record the surveyed alignment location and the displayed latitude and longitude just as a navigation mode is selected. Just prior to takeoff, record the takeoff runway and position on the runway along with the elapsed time and displayed latitude and longitude. Following each maneuver, record the flyover elapsed time, displayed latitude and longitude and flyover altitude. Record applicable notes including offset bearing and range, as well as any INS system alerts including the time of occurrence. For the climb and descent data point, record the altitude and rate of climb at 5,000 feet increments. Following rollout, record the runway, location on the runway, elapsed time and displayed latitude and longitude. Just prior to shutdown, record the surveyed shutdown spot latitude and longitude, the elapsed time and displayed latitude and longitude. During the entire flight, record qualitative comments concerning the utility of the INS displays and navigation accuracy for navigating to and visually finding the surveyed flyover points in a maneuvering environment.

3.3.4.5. Procedure

During preflight planning, choose a flyover point in a working area (preferably a Restricted Area) that allows low and medium altitude maneuvering as well as supersonic flight at low and medium altitudes in the case of a supersonic test aircraft. A flyover point within 5 to 15 minutes of the home airfield is optimum; however, if a longer transit is required, choose flyover update points every 5 to 15 minutes between the home airfield and the maneuvering flyover point. Choose an initial airspeed that conserves fuel. A low altitude is best since flyover data will be required during the transit. Perform a flyover point as described in the dynamic non-maneuvering position accuracy section in the maneuvering area. Climb to a moderately low altitude in the case of an attack aircraft and a medium altitude in the case of a fighter aircraft and perform a maximum power acceleration to the limit airspeed or mach number of the aircraft. A shallow dive can be used to expedite the maneuver as long as it can be safely performed at the chosen altitude. When a dive is used, an initial altitude above the test altitude should be chosen. Generally, the rate of descent should never exceed 1/2 of the aircraft altitude for safety purposes.

Following the acceleration, decelerate to a good maneuvering speed while performing a 1.5 g or less turn, return to the flyover point and perform a flyover data point. Use a typical, low altitude for the flyover as described in the dynamic nonmaneuvering position accuracy test. Next climb to a medium low altitude and perform a constant 3 g,

360° turn. Use the best maneuvering airspeed, or the cornering airspeed, for the test. The cornering airspeed will be available from the aircraft operating manual. Return to the flyover location and repeat the flyover data point. Repeat at 5 g and then at the maximum aircraft level g. For the fighter aircraft test, perform the maximum g test at a medium altitude. Next, climb to a medium low altitude, set a good maneuvering airspeed and perform an aileron roll at 1/4 stick deflection. Return to the flyover point and perform a flyover data point. Repeat at 1/2 stick deflection and then at full stick deflection or at the aircraft roll limit, whichever is greater. Again at a medium low altitude provide a step rudder input at 1/4 and 1/2 rudder deflection and finally at either full rudder deflection or the aircraft rudder input limit. Perform a flyover update between each input.

Next, perform a maximum rate climb to a medium-high altitude, followed by a rapid descent to the flyover altitude. During the descent, ensure that no aircraft limits are exceeded. In general, when below 5,000 feet AGL, do not exceed a rate of descent greater than one half of the aircraft altitude. Perform a flyover update.

Finally, climb to a medium low altitude and perform a series of rolling push-overs and pull-ups, increasing the g to the aircraft limits. After reaching the aircraft limit, perform a final flyover data point. Return to the home airfield performing a flyover data point each 5 to 15 minutes of transit time as required. After the landing rollout, record the runway and runway position, elapsed time and displayed latitude and longitude. Before shut down, record the shut down spot surveyed latitude and longitude, the elapsed time and the displayed latitude and longitude. During the entire flight, watch for INS system discretes and record them as notes along with the time of occurrence. Thoroughly investigate all failure discretes after the flight. In addition, qualitatively evaluate the INS controls, steering cues, displays and accuracy as an aid for finding the flyover points in the maneuvering environment.

3.3.4.6. Data Analysis and Presentation

For data where the aircraft did not fly directly over the flyover point, use the recorded bearing and range at closest point of approach to find the actual latitude and longitude. Convert the bearing to the point to true bearing and then resolve the vector into north-south and east-west components. Next, convert the components into differences in latitude and longitude. In the north-west hemisphere, add the difference in latitude when the point is to the south of the aircraft. Add the difference in longitude when the point is to the west of the aircraft. Use the equations below:

$$T_{bearing} = M_{bearing} - V$$
$$\Delta_{Lat} = \frac{(\Delta nm)}{(\cos(LAT))} \qquad (25)$$

Subtract the displayed latitude and longitude from the surveyed latitude and longitude or the offset corrected latitude and longitude as appropriate. Convert the latitude and longitude difference to nm using equation (25). Plot the data as latitude and longitude error versus elapsed time. Annotate the flyover points with the type of maneuvers performed just before each was taken. Check the plot for any significant change in the slope of the error plot and relate any changes to the effect these maneuvers have upon INS accuracy. Further relate the error to the loss of INS accuracy during mission relatable ACM for fighters and evasive maneuvering inbound to the target for attack aircraft.

If system alerts are noted during the flight, check for a significant change in the error rate curve following the time the alert is noted. Thoroughly investigate any INS alerts that imply degraded accuracy but do not result in a change in the error curve and do not result in malfunctions being found during the ground checks. The alerts should be related to the possibility of unnecessarily aborted sorties (false alarms). Relate the utility of the INS controls, displays, steering cues and integration within the aircraft to the utility of the INS as an aid for navigating to the target position and later returning to the home airfield, all while performing evasive maneuvers.

3.3.4.7. Data Cards

Sample data cards are provided as card 41.

CARD NUMBER ___ TIME ____ PRIORITY L/M/H

DYNAMIC MANEUVERING POSITION ACCURACY

[AFTER PERFORMING THE INITIALIZATION AND ALIGNMENT TEST, SELECT A NAVIGATION MODE. START THE STOP WATCH AND RECORD THE LATITUDE AND LONGITUDE. RECORD DATA AT THE TAKEOFF ROLL POINT. AFTER TAKEOFF, SET ___ KIAS, CLIMB TO _____ FEET MSL AND ASSUME NAVIGATION TO THE FLYOVER POINT, TAKING FLYOVER DATA ONCE THERE. PERFORM EACH MANEUVER AND BETWEEN EACH TAKE A FLYOVER DATA POINT. RECORD AS NOTES, OFFSET FROM POINT AND SYSTEM ALERTS. RECORD QUALITATIVE COMMENTS CONCERNING THE UTILITY FOR MANEUVERING FLIGHT OF NAVIGATION DISPLAYS/CONTROLS, STEERING CUES AND NAVIGATION ACCURACY. RECORD DATA AFTER ROLLOUT AND BEFORE SHUTDOWN.]

SURVEYED ALIGNMENT LOCATION _____ _____

DISPLAYED WHEN SELECTED _____ _____

DESCRIBE TAKEOFF POINT:

ELAPSED TIME AT TAKEOFF _____

DISPLAYED AT TAKEOFF _____ _____

NOTES:

Card 41: Dynamic Maneuvering Position Accuracy Data Cards

DYNAMIC MANEUVERING POSITION ACCURACY

AIRSPEED ___ KIAS

ALTITUDE _____ FEET MSL

FLYOVER POINT _____ _____

MANEUVER	ALT/AIR-SPEED (FT MSL/KIAS)	TIME	DISPLAYED	FLYOVER ALT (FT MSL)	NOTES:
INITIAL FLYOVER					
MAX LEVEL ACCEL					
LEVEL TURN 3G					
LEVEL TURN 5G					
LEVEL TURN _G					

Card 41: Dynamic Maneuvering Position Accuracy Data Cards (Continued)

DYNAMIC MANEUVERING POSITION ACCURACY

MANEUVER	ALT/AIR-SPEED (FT MSL/KIAS)	TIME	DISPLAYED	FLYOVER ALT (FT MSL)	NOTES:
1/4 STICK ROLL					
1/2 STICK ROLL					
FULL STICK ROLL					
1/4 RUDDER					
1/2 RUDDER					
FULL RUDDER					

Card 41: Dynamic Maneuvering Position Accuracy Data Cards (Continued)

DYNAMIC MANEUVERING POSITIONAL ACCURACY

MANEUVER (CLIMB OR DESCENT)	ALT/RATE OF CLIMB AT 5,000 FT INCREMENTS (FT MSL/FPM)	TIME	DISPLAYED	FLYOVER ALT (FT MSL)	NOTES:

Card 41: Dynamic Maneuvering Position Accuracy Data Cards (Continued)

DYNAMIC MANEUVERING POSITION ACCURACY

MANEUVER	ALT/AIR-SPEED (FT MSL/KIAS)	TIME	DISPLAYED	FLYOVER ALT (FT MSL)	NOTES:
ROLLING PUSH-OVERS/ PULL-UPS					

DESCRIBE LOCATION OF ROLLOUT:

ELAPSED TIME AFTER ROLLOUT _____

DISPLAYED AFTER ROLLOUT _____ _____

SURVEYED SHUTDOWN LOCATION _____ _____

ELAPSED TIME AT SHUT DOWN _____

DISPLAYED AT SHUTDOWN _____ _____

QUALITATIVE COMMENTS CONCERNING UTILITY DURING MANEUVERING FLIGHT OF NAVIGATION DISPLAYS/CONTROLS:

INS STEERING CUES:

MANEUVERING ACCURACY:

Card 41: Dynamic Maneuvering Position Accuracy Data Cards (Continued)